QUANTITATIVE MODELING OF THE CARBON STOCK IN THE FOREST ECOSYSTEMS OF BULGARIA

Ekaterina Ivanova Ivanova

Space Research and Technology Institute – Bulgarian Academy of Sciences

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Introduction

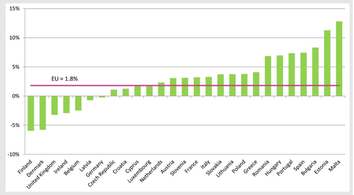
This work aims to further explore the potential of remote sensing technologies in the study of global carbon balance, and to encourage their uses in national forest management. To achieve this purpose, ND56 Landsat 8 OLI model – the original ND45 Landsat ETM+ model by Goodenough et al. [1] – was applied to quantify forest carbon stocks nationally. .

The quantification of forest carbon stock is important because::

- ❖The forests are the major carbon sink among the terrestrial ecosystems, with considerable proportion of above-ground biomass (AGB). They store approx. 45 % of terrestrial carbon and take up approx. 33 % of anthropogenic carbon emission!
- ❖Carbon stock and carbon sequestration have been used as important indicators for climate regulation ecosystem services assessment and mapping in support of biodiversity and global climate changes mitigation!
- ❖The forest above-ground biomass (AGB) quantities are fundamental to calculate provisions of timber and wood fuel!

Change in CO2 emissions, 2017/2016 (estimated by Eurostat

Increases (%)		Decreases (%)	
Malta	+12.8	Finland	-5.9
Estonia	+11.3	Denmark	-5.8
Bulgaria	+8.3	UK	-3.2
Spain	+7.4	Ireland	-2.9
Portugal	+7.3	Belgium	-2.4
.....	.....	Latvia	-0.7
.....	.....	Germany	-0.2



Bulgaria is among the countries with the most polluted air in Europe. According to Eurostat in 2017 the carbon dioxide emissions in the EU increased by 1.8%, compared with the previous year, with Bulgaria among the top 3 pollutants in EU [2]

Methods

Landsat 8 OLI/TIRS C1 Level-1 data were downloaded on 23 and 24 July 2018 from Landsat 8 collection, freely available through [3]. Nine geometrically correct images, covering the whole territory of Bulgaria, were selected, following two main searching criteria: vegetation period from May to October and cloudiness less than 10%. Satellite data with the best meteorological conditions were found for the years 2015, 2016 and 2017.

The following steps were performed in order to quantify C stocks in Bulgarian forest ecosystems

Data Processing
- Data processing for radiometric correction, i.e. to convert the data from DNs to real TOA reflectance
- Data filtering and mosaicking, i.e. applying an 11x11 average filter for all satellite scenes to mitigate extreme values caused by atmospheric or environmental disturbances

iND56 ndex calculation
- $ND56_{Landsat8} = 128 * [(b5 - b6)/(b5 + b6)] + 128$

Forest ecosystems
- CLC2012 data were used for obtaining forested areas and forest types

AGB calculation
- Forest above-ground biomass calculation:
- $AGB_{Volume} = -478.58 + 4.5041 * ND56_{Landsat8}$

C-stock calculation
- $Cstock_{311} = AGB * 665 * 0.5$
- $Cstock_{312} = AGB * 460 * 0.5$
- $Cstock_{313} = AGB * 562.5 * 0.5$

Results

To avoid image classification procedures, CLC2012 CIS-data set was used for obtaining forest areas and forest types (Figure 2b). Forest land covering classes 311, 312 and 313 from level 3 of the CLC2012 was selected for deciduous, coniferous and mixed forest types, respectively. The forested areas of different forest types were extracted from the mosaicked ND56 vegetation index by overlapping both layers (Fig. 1).

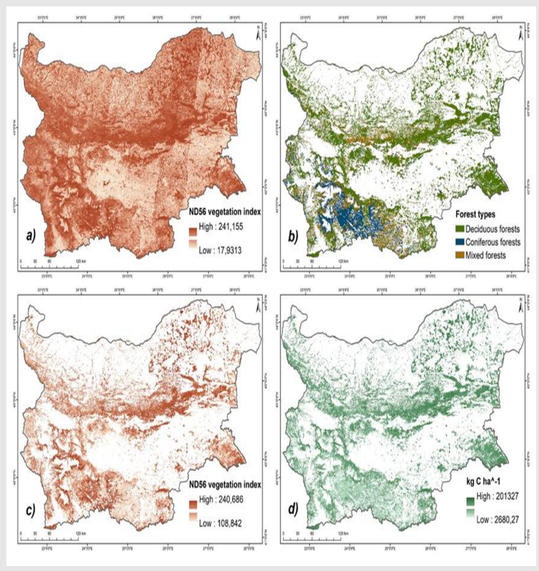


Figure 1. Data layers derived in the ND56 (Landsat 8 OLI) modelling for carbon stock quantification: a) ND56 vegetation index averaged over an 11x11 pixel window; b) Forest types; c) ND56 only over forested areas; d) Carbon stock in kg C ha^{-1}

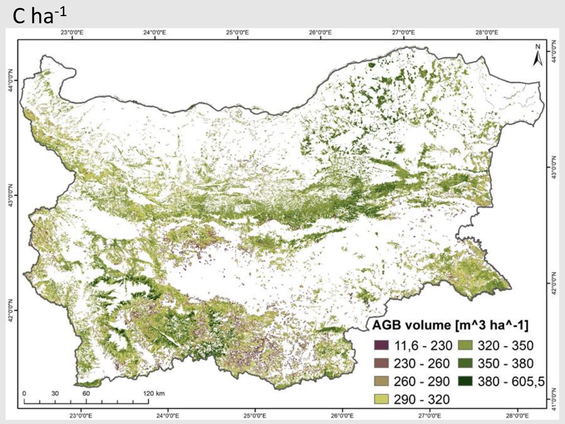


Figure 2. Aboveground biomass volume of forest ecosystems in Bulgaria (m^3 ha^{-1}).

It was calculated that the total amount of carbon accumulated in aboveground part of the forests in Bulgaria is 336.8 million tons for total of 35 317 km^2 forest area. The carbon stored in Bulgarian forests ranges between 2.7 and 201 t C ha^{-1}, depending on the forest type (Fig. 3).

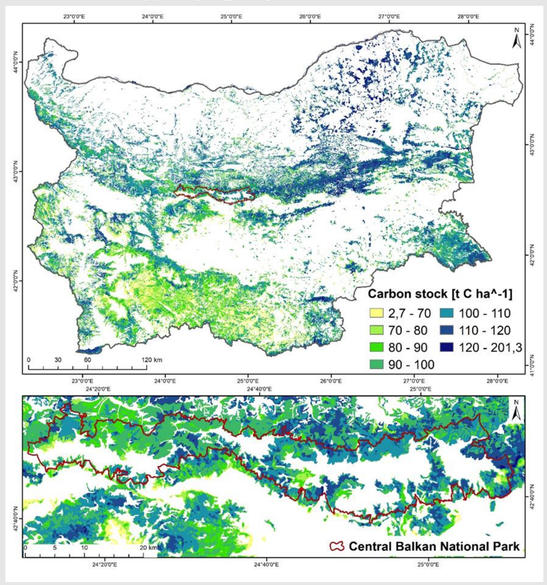


Figure 3. Carbon stock in aboveground forest biomass (t C ha^{-1})

The averaged carbon density value of the total forests is 96.7 t C ha^{-1}, lowest in coniferous (72.6 t C ha^{-1}) and highest in broad-leave forests (104.9 t C ha^{-1}) .

The major part of the total carbon in Bulgarian forest ecosystems is stored in deciduous forests (71.5 %).

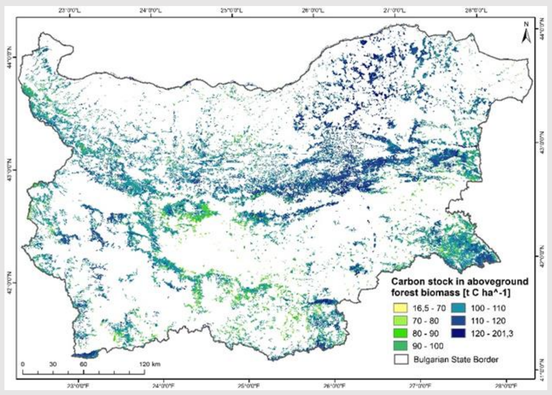


Figure 4. Carbon density of deciduous forests

About 16.8 % are retained in mixed forests and only 11.7 % in coniferous forests (Fig. 4, 5 and 6).

Although the aboveground biomass volume modeled fluctuates widely, in most of the forest ecosystems it varies from 160 to 400 m3 ha^{-1}.(Fig. 2)

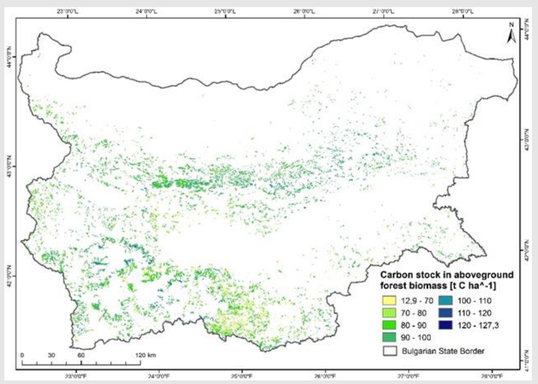


Figure 5. Carbon density of mixed forests

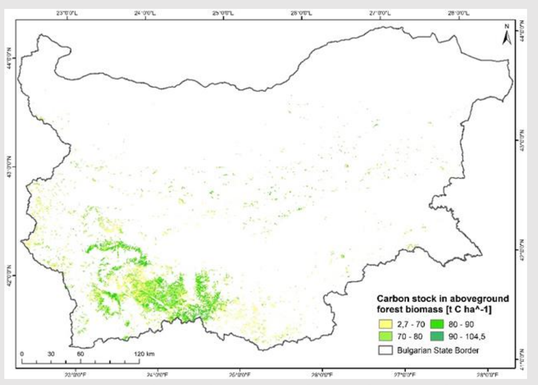


Figure 6. Carbon density of coniferous forests

Main findings:

- ❖The results obtained in this paper are comparable to those of other studies obtained by other methods
- ❖The ND56 Landsat 8 model, originally developed for Canadian boreal forests, is adaptive for the spatial explicit quantification of forest aboveground carbon stock on the territory of Bulgaria
- ❖The maps generated in this study as spatial variables of forest AGBs and carbon stocks can be used as reference data in future studies on carbon stock

Forest type	Forested area [ha]	Total carbon stock [t]	Carbon stock density [t C ha^{-1}]		
			Minimum	Maximum	Mean
Deciduous forests	2 337 881.5	240 877 800	16.5	201.3	104.9
Coniferous forests	542 771.6	39 146 490	2.7	104.5	72.6
Mixed forests	651 057.9	56 740 950	12.9	127.3	87.5
Forest – total	3 531 711.0	336 765 240	2.7	201.3	96.7

Tabl. 1. Carbon stock of aboveground biomass in Bulgarian forest ecosystems

Conclusion

ND56 Landsat 8 OLI model was applied in this study as an adaptation of the original ND45 Landsat ETM+ model in attempt to highlight the potential of remote sensing techniques in forest ecosystem research. As a result, a spatially-explicit quantification of the variability of aboveground carbon stock and biomass for the entire forested area of Bulgaria was performed at 30x30 meters resolution. The detailed maps show that the AGB volume in the Bulgarian forests ranges from 11.6 to 605.5 m3 ha^{-1}, and the carbon stock from 2.7 to 201.3 t C ha^{-1}, depending on the type and quality of the forests. It was estimated that the total amount of carbon accumulated in the aboveground part of the forests in Bulgaria is 336.8 million tons for a total of 35 317 km2 of forest area.

References:

1. Goodenough, D. G., Chen H., Dyk A., Li J., 2005. Multisensor data fusion for aboveground carbon estimation. Proc. XXVIIIth General Assembly of the International Union of Radio Science (URSI), New Delhi, India, vol. CD 400:1–4.
2. Eurostat news release, 4 May 2018. [Online]. Available at: http://ec.europa.eu/eurostat/web/products-press-releases/-/8-04052018-BP. (Accessed: 17-Aug-2018)
3. USGS Science for a changing world. Landsat collection 1 Level-1 (Landsat 8 OLI/TIRS C1 Level-1). [Online]. Available at: https://earthexplorer.usgs.gov/ (Accessed: 23-Jul-2018 and 24-Jul-2018).

Conclusion (cont.)

These results are comparable to others under similar environmental conditions in Europe. The present study is the first attempt for spatially explicit quantification of carbon stocks in aboveground forest biomass at the national level for the territory of Bulgaria, based on data from remote sensing.